Introduction

The central idea of Biological evolution is that all life on earth share a common ancestor. Evolution can be defined as **descent with modification**, a phrase Darwin used in proposing that earth's many species and descendants of ancestral species that were different from present day species. **Evolution** can also be defined more narrowly as a change in the genetic composition of a population from generation to generation.

A brief description of main theories concerning the origin of life is presented in this chapter. Some evidences in support of evolution have also been provided. The Hardy-Weinberg principle and factor that change the allelic frequencies will also be discussed.

24.1 The Evolution of the Concept of Evolution

Understanding evolution is critical for understanding biology. Evolution is the only scientific explanation for **diversity of life**. It explains similarities among vast variety of life. There are many concepts about evolution. Two major and contradictory concepts of evolutionary thoughts are:

a) Special Creation b) Theory of evolution

24.1.1 Concept of Special Creation

The belief that the origin and diversity of life result from super natural event at a particular time in the past, whereby each species was created separately (from the act of God) is called special creation. The supporter of special creation is called **creationists**. This theory is supported by most of the world's major religions and civilizations. This concept is based on the references of Holy books. According to their interpretations that Allah has created everything in the universe in **six days** and human was created at sixth day. In fact, the **faith** accepts things for which there is no evidence in the scientific sense. This means that logically there can be no intellectual conflict between scientific and theological account of creation, since they are mutually exclusive **realms of thoughts**. In most cases the **scientific truth** to the scientists is **tentative**, but **theological truth** to the believer is **absolute**.

Evolution rarely follow a straight line from species to species. Instead it is more like a tree with many bran-ches. Some branches lead to new branches, while other become dead ends.

24.1.2 Concept of Evolution

In biology, evolution is the change in the characteristics of a species over several generations and theory of evolution is based on the idea that all species are related and change over time. The supporters of evolution are called **evolutionists**. According to

their point of view, universe and man did not always exist in their present form but result of many changes from lower to higher order. They also reject the theory of special creation. According to **big bang theory** the life began on earth about **3.5 billion** years ago. The fossil record supports this hypothesis that life originated from simple **prokaryotic organism** and then **eukaryotic organisms** developed from this prokaryote about **1.9 – 2.1 billion** years ago. The present day biodiversity is the result of these continuous evolutionary changes. The concept of evolution did not begin by Darwin and publication of his book "Origin of Species". The evolutionary concepts were present at the time of **Aristotle** about (384-322BC).

24.1.3 The Process of the Evolution of Man in the Holy Quran

The Quran is clear in its support that humans came from lower beings and that creation had a process involving diverse successive stages.

Allah Almighty started the creation of life on Earth, and then left it to evolve as a result of learning from the adaptation to various environments, which intervention from Him to make His creation better. As far as origin of man is concerned.

Allah Says in Quran "O mankind! Be careful of your duty to your Lord Who created you from a single soul and from it created its mate and from them has spread a multitude of men and women". *(Surah Nisa, Verse-1)*

This verse tells us that the beginning of life was a single soul, then its mate came out of it. Biological science tells us that the earliest form of life was represented by single cell organisms found in water, then these multiplied by splitting themselves. With the course of time, reproduction started to be by mating pairs, instead of the archaic forms of splitting or dividing.

Allah Says in Quran "Allah is He) who has made everything He created better and He began the creation of the human (being) out of clay". *(Surah Sajda, Verse-7)*

In this verse, we are told that Allah (Praise to Him) began the creation of human beings out of clay, but that was the beginning, then He improved His creation making it better.

The most relevant word in this verse is "**began**" (bada-a), which tells us clearly that creation happened in a process that had a beginning, not just at once.

Allah Says in Quran "He has created you in diverse (and successive) stages". *(Surah Nooh, Verse-14)*

This verse may be interpreted to refer to the successive stages of the development of a foetus in its mother's womb. However, it can also be interpreted to refer to the successive stages of the human evolution.

Allah Says in Quran "We created the human being from stinking, smooth, and wet

clay". *(Surah Al-Hajar, Verse-28)*

This verse gives a very specific description of the environment where life started. It refers to swamps where still water in combined with the earth soil, which creates stinking but smooth clay easy to take different forms.

.This is exactly what biologists have come up with to explain the beginning of life on Earth.

Allah Says in Quran "It is He Who created you, fashioned you perfectly, and made you with the right proportions (straightened you up, to walk in an upright position". *(Surah Infitar, Verse-7)*

This verse may refer to three main stages of the creation of human beings. The first was creation of a living cell (The Arabic verb Khlaqa, created). The second was the change from unicellular prokaryote organism to the multi-cellular eukaryote organism (the Arabic verb sawwa, fashioned you perfectly). The third was the human departure from the animal stage (The Arabic verb 'adala' made you walk in an upright way).

Allah Says in Quran "Roam the earth and observe how the creation was initiated". *(Surah Ankabut, Verse-20)*

This verse is a direct commandment to humans telling us to travel the earth and observe how creation was brought forth. Interesting thing is that Darwin followed this verse unknowingly and discovered how creation formed.

24.1.4 Origin of Life According to Concept of Evolution

The **vent hypothesis** suggests that life may have begun at **submarine hydrothermal vents**. The first sea **hydrothermal vent** was discovered in 1977 in Pacific Ocean. The fossil found in these vents are about 3.5 billion years old. These fossils belong to a group of prokaryotes, *e.g.* the archaeobacteria (now called archea). It is also believed that the early atmosphere of earth was oxygen free, hot and ozone less. Therefore, frequent exposure of ultra violet radiation was there. This primitive earth's atmosphere has very little nutrients and first prokaryotes were **absorptive heterotrophs**. Later chemoautotrophs were evolved. The **photosynthetic organism** evolved about 3.2 billion years ago. This first photosynthetic organism used hydrogen sulphide as source of hydrogen for sugar molecule instead of water. These prokaryotes still use hydrogen sulphide (H_2S) as source of hydrogen for carbohydrate and produce sulphur (S) as by-product. Later on when cyanobacteria evolved, these started using H_2O as source

Focus Concept of Evolution

The theory of evolution states that species change over time. The primary mechanism for this change is natural selection. The fossil record, morphology, biogeography, comparative anatomy, embryology and molecular biology all provide evidences for evolution.

of hydrogen in synthesizing carbohydrates and liberated O_2 as a by-product. This O_2 accumulated in atmosphere. Thus slowly and gradually **ozone layer** formed. This ozone layer acts as filter for ultraviolet radiations from the sun. When eukaryotic photosynthetic organism evolved about 1.9 – 2.1 billion years ago, the production of O_2 increased many folds and ozone layer got thicker and more protective for life on land. This increased the biodiversity on earth.

24.2 Evidences of Evolution

The evidences to support theory of evolution is provided by many sources. Some important evidences are discussed here.

i) Evidence from Biogeography

The study of the geographical distribution of fossils and living organisms is called biogeography. A comparison of recently formed fossil types of living organisms in the same geographic area shows that new organisms arise in area where similar forms already lived. Thus, **armadillos** appeared in North and South America where **glyptodonts**, lived in the past. Modern kangaroos appeared only in Australia, which evolved from extinct giant kangaroo. Darwin found 13 species of finches in Galapagos Islands, which are not found anywhere else in the world, as far as he knew. He concluded that the finches had evolved from a common ancestral group that probably reached the island many generations earlier. In the isolation of the **Galapagos island**, the original finches had probably evolved into the 13 species.

The study of biogeography supports the theory of evolution as it is found that closely related species are usually found in close physical proximity to one another. The fossils from these regions resemble modern organisms. This suggests that these species share a common lineage.

Age of Earth

The most recent estimate of the age of the earth was published in the journal nature in August, 2005. The age of the earth as estimated from the age of meteorite is 4569 million years old.

ii) Evidence from Palaeontology

The study of past life with the help of fossils is called palaeontology. The study of forms of life existing in prehistoric or geologic times, as represented by the fossils (Lt = fosilium = something dug up) of plants, animals and other organisms.

Palaeontology supports the study of evolution because it shows a descent of modern organisms from common ancestors. Palaeontology indicates that fewer kinds of organisms existed in past eras, and organisms were probably less complex. **Palaeontologists** descend deeper and deeper into layers of rock, the variety and complexity of fossils decrease. The fossils from the upper most rock layers are most like current forms. The oldest known fossils are of prokaryotes. Therefore, prokaryotes are

considered as ancestors of all life forms on earth. The fossil record may allow us to trace the history of one particular organism, *e.g.* the fossil record of different genera and species of horses indicate that **earliest horses** had four toes. Then after a long period of time, the number of toes reduced to three. In modern day horses, the large central toe is present which ends in a hoof. Thus paleontology supports the theory of evolution. (Fig.24.1)

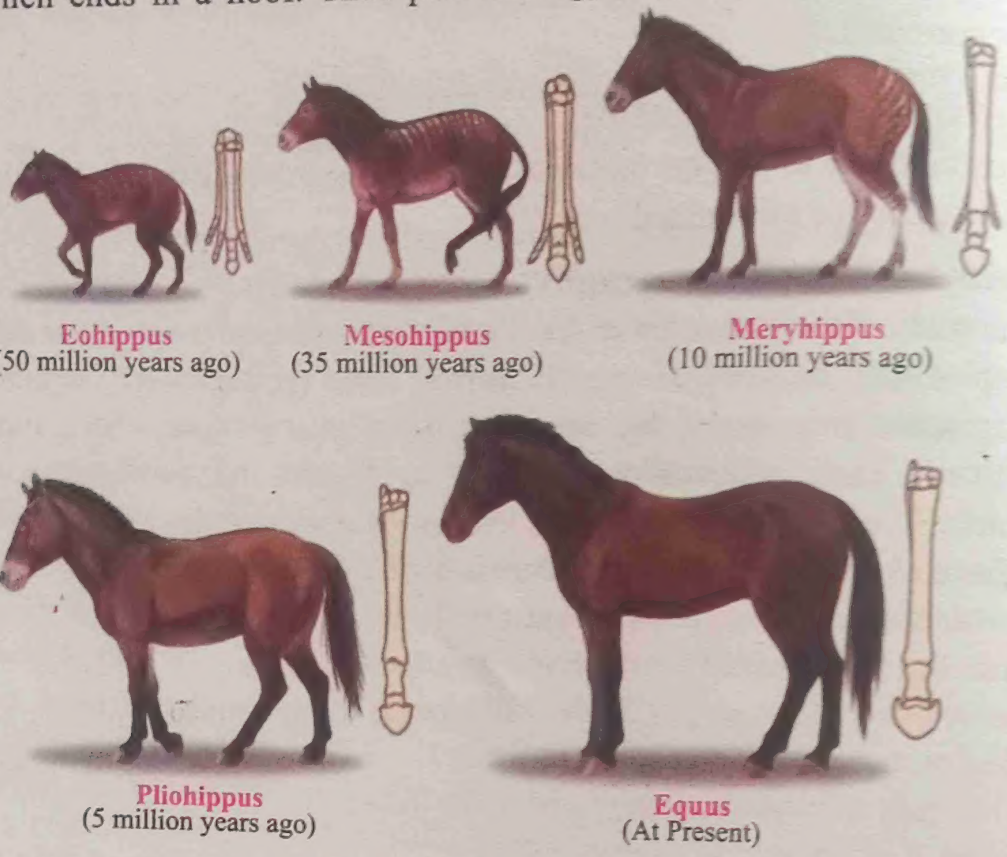

Fig. 24.1: Evolution of Horse

iii) Evidence from Comparative Anatomy

Anatomy is a field of biological sciences which is concerned with the identification and description of the internal body structures of living things.

The study of comparative anatomy predates the modern study of evolution. Early scientists like **Buffon and Lamarck** used comparative anatomy to determine relationship between species. They believed that organisms with similar structures have originated from common ancestor. Today, comparative anatomy can serve as the first line of reasoning in determining the relatedness of species. However, there are many hidden dangers that make it necessary to support evidence from comparative anatomy with evidence from other fields of study.

Homologous and Analogous Structures

Homologous are those structures which are similar in structure but may or may not have the same functions *e.g.* the forelimbs of different mammals like human, cat,

whale and bat have same basic pattern of bones: However, their fore limbs have different function. This indicates that these mammals have common ancestor. (Fig.24.2)

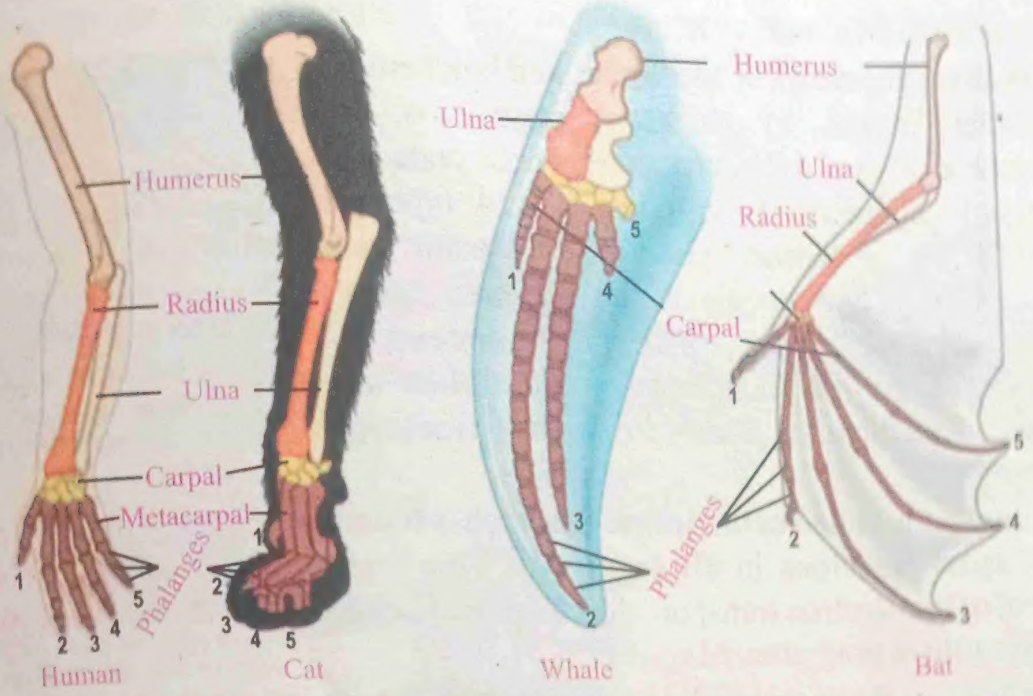

Fig. 24.2: The fore limbs of Human, Cat, Whale and Bat showing Homologous Structure

The homologues struct-ure shows **divergent evolution**.

Analogous structures are those structure which are different in structure but similar in function. These structures perform similar function but may be different in their basic pattern *e.g.* the wings of bats and birds look similar from outside. They also have the same function. However, wing evolved independently in two groups of animals.

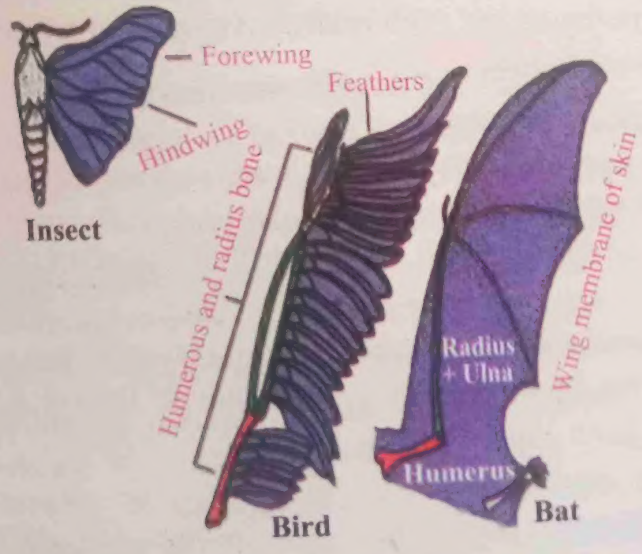

Fig. 24.3: Analogous Structure of Birds, Bat, Insects

Extra Information

Some snakes have hipbones, which show they once had four legs like lizards, their close cousins.

Moreover, the bird wings and insect wings are also analogous traits. This type of evolution is called **convergent evolution**. (Fig. 24.3)

Evidence from Molecular Biology

There are certain key molecules and biochemical mechanisms shared by different organisms. All organisms use DNA and RNA for their genetic code. The DNA in all organisms is composed of 4 types of nucleotides *i.e.* Adenine, Guanine, Cytosine and Thymine. The ATP molecule is the common energy currency in all organisms. The process of photosynthesis, cellular respiration, transcription and translation are all identical or very similar in various type of organisms.

Extra Information

Inside some whales and dolphins are small limb bones which show that once had back legs and that their ancestors walked on land. These occasion-ally reappear as tiny rear flippers.

A molecule called **cytochrome C**, which is found in all organisms. This molecule performs same functions in all organisms. This highly conserved protein is a key component of the electron transport chain (a part of cellular respiration). The cytochrome C also plays role in programmed cell death.

Similarity, these molecules make sense that these are important molecules and therefore, present in most of organisms. However, it would not make sense if each of these molecules appeared independently in each species. These shared biochemical molecules and pathways provide strong evidence for common descent and evolution.

24.3 Evolution of Eukaryote from Prokaryotes

Fossil records indicate that eukaryotes evolved from prokaryotes somewhere, between 1.9 - 2.1 billion years ago. Two hypothesis have been proposed to describe the evolution of eukaryotes. These hypotheses are membrane invagination hypothesis or theory and endosymbiotic hypothesis or theory.

24.3.1 Membrane Invagination Theory

The invasions of the host prokaryotes cell probably were successful because the host cell membrane infolded to surround both invading prokaryotic cells and there by transport them into the cell. The membrane did not dissolve but remained intact, and there by created a second membrane around the **promitochondria** and **prochloroplast.** It is also known that in modern day eukaryotes the inner membrane of both mitochondria and chloroplast contain structures more similar to prokaryotes than eukaryotes. Whereas the outer membrane retains eukaryote characteristics. It is also

Extra Information

You might think that you are special, but believe it or not you share about 50% of your DNA with a banana and approximately 31% of your genes with yeast, which is a single celled organism.

suggested that continued membrane infolding created the endomembrane system. It can be said that possibly the first eukaryotic cell type was born from prokaryotic, symbiotic, multi cell interactions. (Fig.24.4)

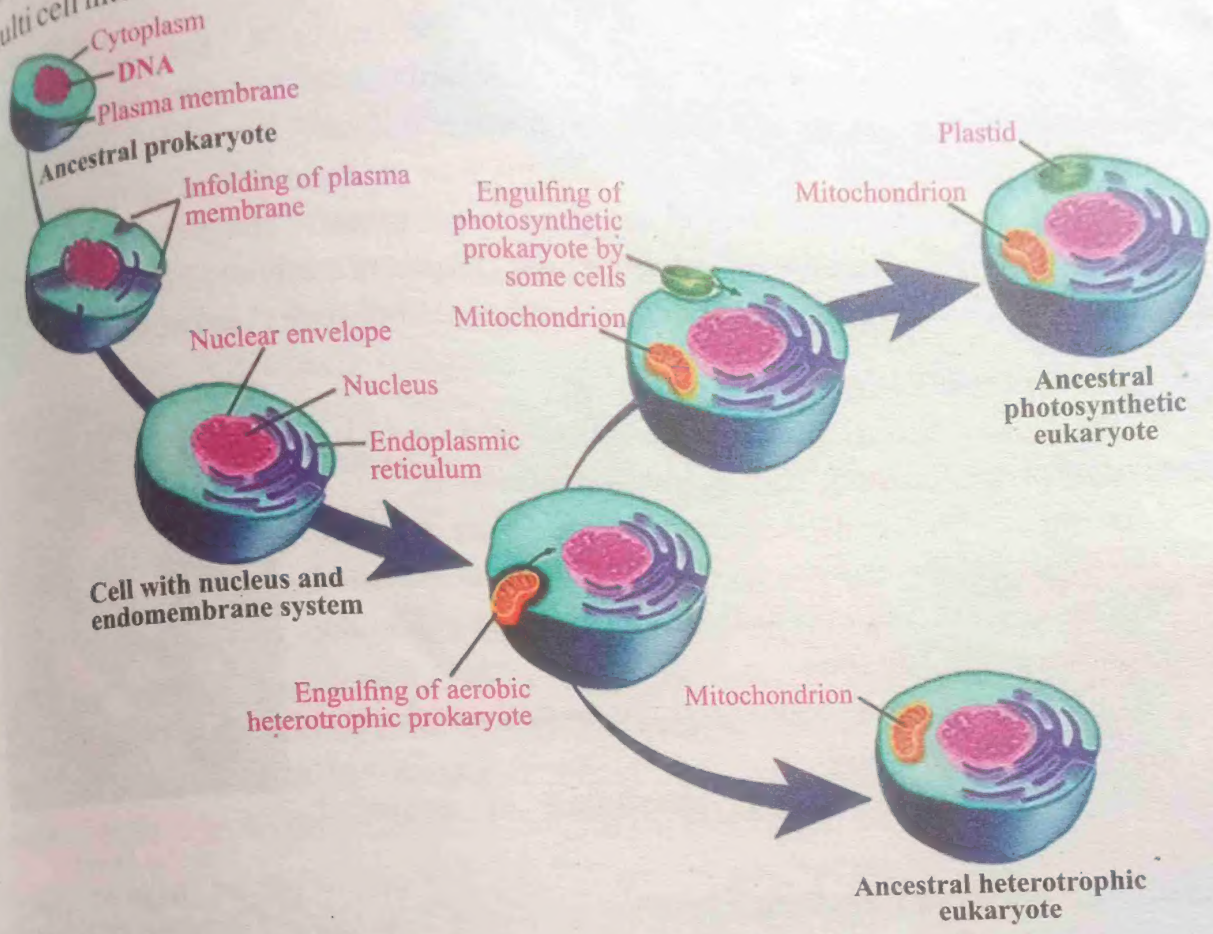

Fig. 24.4: Endosymbiotic Theory and Cell Invagination Theory

24.3.2 Endosymbiosis Theory

Research conducted by **Lynn Margulis** supports the hypothesis that two separate mutually beneficial invasions of a prokaryote cell produced the modern day mitochondria and chloroplast as eukaryotic organelles. In this model, ancestral mitochondria were small heterotrophs capable of using oxygen to perform cellular respiration and thereby create useful energy. They become part of a large cell either by direct invasion as an internal parasite or as an indigestible food source. Later a second invasion brought ancestral chloroplasts, which are thought to be small photosynthetic cyanobacteria. Modern day supporting evidence for endosymbiosis shows that both mitochondria and chloroplasts have their own genes,

Interesting Information

Monkey is different from ape. Monkeys have tails and narrow chest. Apes are tailless and have broad chests.

circular DNA and RNA, and reproduced by binary fission independent of the host's cell cycle. They therefore, appear to be more similar to prokaryotes than eukaryotes.

24.4 Lamarckism

Jean Baptiste de La Marck (August 1, 1744 – December 28, 1829) was a **French naturalist** and early proponent of idea that evolution (descent with modification) occurred and proceeded in accordance with natural laws. Lamarck, however, is remembered today mainly in connection with his now rejected theory of heredity, the inheritance of acquired traits. Lamarck is regarded as a premier authority of plants and invertebrate zoology and well known **toponymist** (Expert of study of places names). He also wrote a book **Philosophie Zoologique** (Zoological Philosophy) in 1809.

24.4.1 Lamarck's theory of Evolution

The theory about evolution presented by Lamarck is called Lamarckism. Lamarck's theory involved two ideas.

i) An organ which is used more and more by an organism becomes bigger and stronger, and one that is not used, becomes weak and eventually disappears. He called this concept use and disuse.

ii) Any feature of an organism that is improved through use is passed to its offsprings.

This concept was called **inheritance of acquired characters.** (Fig.24.5)

Fig. 24.5: Jean Baptiste de La Marck

Examples to Support Lamarck Theory

Evolution of Giraffe

According to Lamarck, the ancestors of giraffe looked like horses with small neck and forelimbs. They lived in areas where there was no surface vegetation. Therefore, they had to stretch their neck and forelimbs to eat leaves from tall plants. Consequently, these parts got elongated. This trait was transmitted in the succe-ssive generations. (Fig.24.6)

Fig. 24.6: Evolution of Giraffe Neck

Extinction of Limbs in Snakes

The snakes are believed to have evolved from lizard like ancestors that had two pairs of limbs. Due to disuse of the limbs, the limbs got weaker and shorter and eventually disappeared.

Flightless Birds

It is believed that the ancestors of birds such as Ostrich were able to fly. Due to some environmental changes, they had a lot of food and well protected. They did not use wings and as a result the wings became **vestigial**.

24.4.2 Drawbacks of Lamarckism

Lamarck's theory of acquired characters couldn't gain popularity and acceptance due to following drawbacks.

i) There is no experimental proof of his theory.

ii) New organs are not formed in organisms by requirement.

iii) It is not necessary that the acquired character transmits into new generation.

Moreover, a German biologist **August Weisman,** in 1880s disproved the Lamarck's theory of inheritance by giving experimental proof. He removed tails of 68 mice, repeatedly for many generations, and reported that no mice were born without a tail or even with shorter tail. This rejects the theory of inheritance of acquired characters.

24.5 Darwinism

Charles Darwin was born on February 12, 1809 in **Shrewsbury,** England and died at **"Down House"** in Kent on April 19, 1882. He is known as father of evolution. He was selected as naturalist on **HMS Beagle** (A British naval ship about to sail around the world to expand the navy's knowledge of natural resources). He wrote the book **"Origin of species by means of natural selection".** In his book, he has given the idea of evolution by means of natural selection. (Fig.24.7)

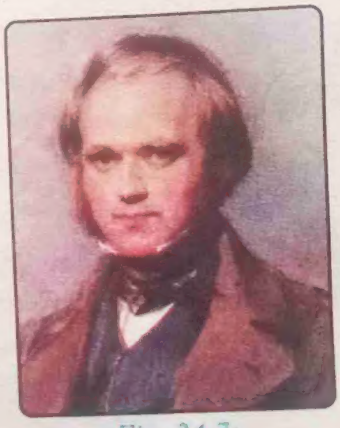

Fig. 24.7: Charles Darwin

24.5.1 Darwin's Observations During his Voyage

In 1831, when Darwin was just 22 years old, he set sail on scientific expedition on a ship called the HMS Beagle. He was the naturalist on the voyage. As a naturalist, it was his job to observe and collect the specimens of plants, animals, rocks and fossils wherever the expedition went ashore. During this long journey Darwin made observations.

Darwin Finches

One of the most famous species that Darwin observed were finches that lived on Galapagos Islands. He found 13 different species of finches and noted the main differences amongst the finches on each island which were their beak shape. He observed that finches on each island had beak shapes that were applicable for the type of food that was available on the island. (Fig.24.8)

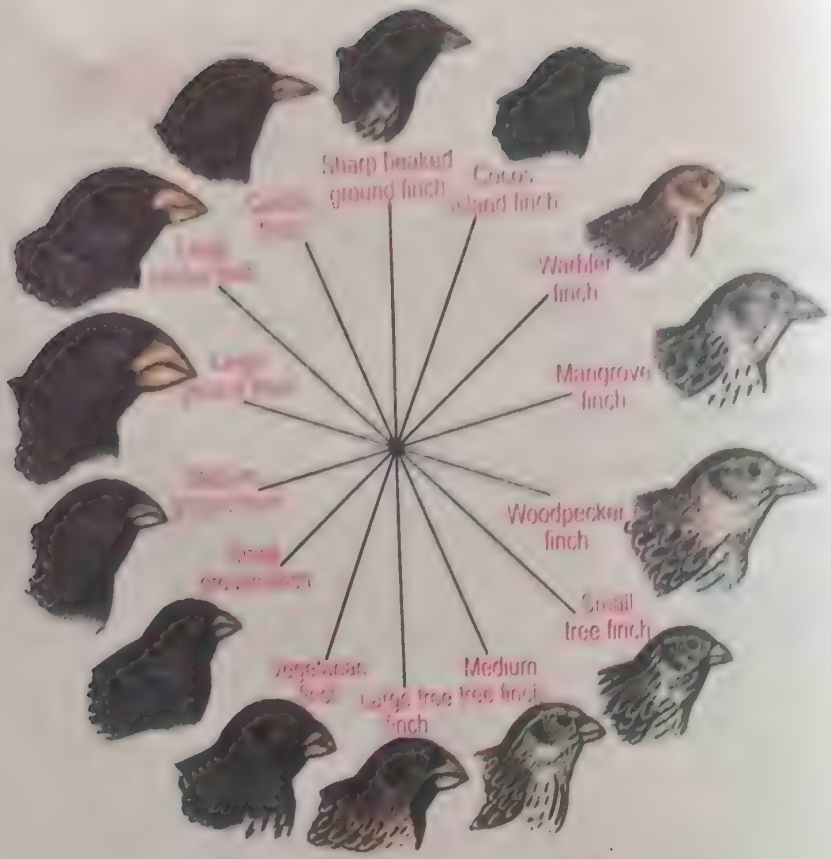

Fig. 24.8: Darwin Finches of Galapagos Island

Giant Tortoise

Darwin also observed giant tortoises in Galapagos Islands. The Galapagos Islands were named for their giant tortoises. Darwin noticed that tortoise on one island had **saddle-shaped shell**, while those on another island had **dome shaped shell**. This observation made Darwin to think about origin of species. (Fig.24.9)

Dome Shaped Shell Saddle Shaped Shell

Fig. 24.9: Tortoises of Galapagos

Fossils of South America

In South America, Darwin found fossils that resembled modern animals however, they had differences is size and adaptations. It made him realize that living things had ancestors and that species change over time.

Development of the theory of Evolution

Although Darwin presented his theory of **natural selection** in 1859 in his famous book "Origin of species" but he started his work in 1836 after return from 5 years trip of HMS Beagle. In the meanwhile, he collected the data to support his idea. His theory of evolution is not only based on his observations, but he was also inspired by the work of many other scientists of his time. Therefore, he also shared the ideas of these scientists in the development of his theory.

Contribution of Charles Lyell

He was well known English **geologist**. He wrote a book **"Principles of Geology"**, in his book Lyell argued that gradual geological processes have gradually shaped Earth's surface. Darwin was impressed and he took his book with him on the Beagle voyage.

> **Extra Information**
>
> The size of Galapagos tortoise is about 4 feet, weight 475 pounds, average life span is 100 years and it feeds on plants.

James Hutton (1726 - 1797)

He was Scottish geologist, chemist and naturalist. He has given the concept of **uniformitarianism**, which explains the features of the earth's crust by means of natural processes over geological time. He was also the first person to propose a mechanism of natural selection to account for evolutionary change over time. Darwin was also inspired by Hutton's work.

Thomas R. Malthus (1766 – 1834)

He was an English **economist**. He wrote an **essay on population**. In the essay, he argued that human populations grow faster than the resources they depend on. When populations become too large, famine and disease breakout. In the end, this keeps populations in check by killing off the weakest members. Darwin read the article during his journey and influenced by his thoughts.

Alfred Russell Wallace (1823 – 1913)

Wallace lived at about the same time as Darwin. He also travelled to different places to study nature. However, he developed basically the same theory of evolution while working on distant lands, Wallace sent Darwin a paper he had written. In the paper, Wallace explained his evolutionary theory. This served to confirm what Darwin already thought.

> **Interesting Information**
>
> The phrase "survival of the fittest" associated with Darwin was coined by biologist Herbert Spencer after reading Darwin's work.

Why the theory was attributed to Darwin?

Although the Wallace developed basically the same theory of evolution as described by Darwin. Moreover, Hutton was the first person to propose a mechanism of

natural selection. The Alfred Russell Wallace also motivated Darwin to publish his book about the origin of species by means of natural selection. However, Darwin came up with great supporting evidences from a wide variety of scientific disciplines, including palaeontology, geology, vestigial organ, biogeography and comparative anatomy. Darwin spent more than 30 years in studying and observing nature before concluding his ideas. Therefore, this theory was attributed to Darwin.

Extra Information

At the time of Darwin's death in 1882 his book had been published. The origin of species has been translated into 29 languages including Turkish, Hindi *etc.*

24.5.3 Darwin's Theory of Natural Selection

According to this theory various types of plants, animals and other living things on earth have their origin in other pre-existing types and that the distinguishable differences are due to modifications in successive generations. There are two main points of Darwin's theory of evolution *i.e.*

- Descent with modification
- Natural selection.

Descent with Modification

Descent with modification means passing on the traits from parent organism to their offsprings. According to Charles Darwin, all species descended from only a few life forms that had been modified over time. This descent with modification as he called it, forms the backbone of his theory of evolution.

Natural Selection

Natural selection is the process in nature by which organisms better adapted to their environment tend to survive and reproduce more than those less adapted to their environment. There are four observations about natural selection.

a) Over Production

Each species has the capacity to produce more offsprings that can possibly obtain food and survival. If all offsprings of any species remained alive and reproduce, they will soon over crowd the earth and could destroy all other species. For example if each breeding pair of elephants produces six offspring during its 90 year life span, in 750 years a single pair of elephants will give rise to a population of 19 million. Yet elephants have not overrun the planet.

b) Struggle for Existence

The individuals increase enormously in number but the space and food available remain almost constant. There is always an active competition and three- fold struggle to ensure living, to obtain the maximum amount of food and better place. The struggle for

existence may be:

1. **Intra Specific:** Competition among the organisms of same species.
2. **Inter Specific:** Competition among the organisms of different species living together.
3. **Environmental Struggle:** Struggle against various environmental conditions.

c) **Variations**

The individuals in a population exhibit variation in their traits. Some of these traits improve the chances of an individual's survival and reproductive success, whereas other traits do not. Variation necessary for evolution by natural selection must be heritable.

d) **Survival of the fittest**

As a result of competition among the organisms, the stronger win and survive (variant) while the weaker less variant are rooted out. *e.g.* if there is flood only those organisms that can swim or respire in water, have a better chance to survive and other will die. Darwin called it natural selection. It is also called survival of the fittest.

The process of natural selection thus causes an increase in favorable alleles and decrease in unfavorable alleles with in the population. Over succeeding generations, individual members become better adapted to local, conditions, thus leading to the evolution of new species.

24.6 Neo-Darwinism

Neo-Darwinism also called the **modern evolutionary synthesis**, generally denotes the integration of Charles Darwin's theory of evolution by natural selection, Gregor Mendel's theory of genetics as a basis of biological inheritance, and mathematical population genetics. **Neo-Darwinism** has been one of the most significant, overall developments in evolutionary biology, since the time of Darwin, Neo-Darwinism introduced the connection between two important discoveries: the unit of evolution (gene) with the mechanism of evolution (natural selection).

24.6.1 Hardy-Weinberg Theorem

Godfrey Hardy and **Wilhelm Weinberg** developed relationship between the frequencies of alleles and genotypes in 1908. They pointed out that the frequencies of various genotypes in a population can be described mathematically which is known as Hardy-Weinberg principle; it states that "Both the ratios of genotypes and frequency of alleles remain constant from generation to generation in a sexually reproducing population provided other conditions are stable".

Conditions/assumptions for stability

Hardy-Weinberg principle describes how a population can remain at genetic

equilibrium. **Genetic equilibrium** occurs when there is no evolution within the population. At genetic equilibrium, the gene or allele frequencies are stable. They do not change. There are following conditions that must be met for genetic equilibrium to occur:

1. No mutation (change) in DNA sequence.
2. No migration (moving into or out of a population).
3. Random mating.
4. No natural selection.

These conditions rarely occur in nature. If one or more of the above conditions do not exist, then evolution can occur. As a result, allele frequencies are constantly changing, and populations are constantly evolving.

Problem of Gene Frequency

The allele for grey body B is dominant to black body color b. There are 30% recessive alleles in the gene pool having population of 1000 individuals. Calculate the number of grey body individuals and black body individuals in a population.

Factors that change allele frequencies

There are number of factors which may lead to change in allele frequencies. These factors include.

a) Mutation: It is the change in genome of an organism. It is major source of variations and natural selection.

b) Migration or gene flow: It is the movement of individuals from one population to another. If a foreign individual migrates (comes) into the population is called **emigration**. If an individual migrates (goes out) of the population is called **immigration**. In both cases, allele frequencies will change accordingly.

c) Non-random mating: It is the mating among specific group of individuals in a large population. Individuals will mate more frequently with close individuals than more distant ones. Although new alleles cannot be developed by non-random mating but it can cause an increase in homozygous genotypes.

d) Natural Selection: Populations vary in the type of individuals and their reproductive success. Those individuals who leave more offsprings behind than others, pass on more of their alleles and have a better success rate in dominating the population. The selection may be artificial in which breeder select for the desirable traits.

Hardy-Weinberg Equation

It is not only important in population genetics; public health scientists also use it to estimate the percentage of people carrying alleles for certain diseases. Estimating the frequency of harmful allele is useful for the public health programs dealing with genetic diseases.

Hardy-Weinberg Equation

It is a mathematical equation that can be used to calculate the genetic variation of a population at equilibrium. This equation is an expression of the principle known as

Hardy-Weinberg equilibrium, which states that the amount of genetic variation in a population will remain constant from one generation to the next in the absence of disturbing factors *e.g.* mutation genetic drift etc.

To explore Hardy Weinberg equation, we can examine a simple genetic locus at which there are two alleles, 'A' and 'a'. The Hardy-Weinberg equation is expressed as $p^2 + 2pq + q^2 = 1$ where 'p' is frequency of 'A' allele and 'q' is the frequency of the 'a' allele in the population. In the equation 'p^2' represents the frequency of the homozygous genotype 'AA', while 'q^2' represents the frequency of homozygous genotype 'aa' and '2pq' represents the frequency of heterozygous genotype 'Aa'. In addition, the sum of the allele frequencies for all the alleles at a locus must be '1', so p + q = 1. If the 'p' and 'q' allele frequencies are known, then the frequencies of the genotypes may be calculated using the Hardy-Weinberg equation. In population genetics studies, the Hardy-Weinberg equation can be used to measure whether the observed genotype frequencies in a population differ from the frequencies predicted by the equation. (Fig.24.10)

p = frequency of allele A in population
q = frequency of allele a in population
if there are only 2 alleles for a gene then:
$p+q=1$ or 100%
Allele frequencies can be used to
Determine genotype frequencies too!
$p^2+2pq+q^2=1$

Example: If there are 200 M alleles in the gene pool and 800 m alleles, the

$0.2+0.8=1$

M m

and $(0.2)^2+2(0.2\ 0.8)+(0.8)^2=1$ or 100%

MM	**Mm**	**mm**
0.04	0.32	0.64

The Hard-Weinberg equilibrium is never achieved in nature, but it's very useful in studying populations.

Fig. 24.10: Hardy Weinberg Equation

24.6.2 Genetic Drift

Genetic Drift is a change in allele frequency in a population due to a random selection of certain genes. Mostly mutation within the DNA can have no effect on the fitness of an organism. These changes in genetics can increase or decrease in a population simply due to chance.